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Evolving New Stimulation Process Proves Highly Effective in Level 1 Dual-Lateral Completion

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Abstract

Key Production Co. began using short-radius, moderate length openhole horizontal lateral recompletions in re-entries of wells in a limestone/dolomite reservoir in northwest Texas. They found that a few wells needed some type of stimulation to achieve optimum production rates. A dual lateral (90° opposed) was drilled on one re-entry to improve production performance. This well was in an area of the field with below-average reservoir quality, and production rates were still disappointing even with two lateral sections. Fracture acidizing was the most likely method to achieve the degree of stimulation needed. There was concern that this might lead to unwanted communication with the aquifer zone below the oil column. Conventional stimulation methods could not achieve multiple, well-spaced, limited-sized fractures.

The operator used a new hydrajet-fracturing technology that has shown a very high success rate in other areas to achieve the stimulation needed for this well, and at acceptable cost. Six separate fractures were placed at selected locations along each of the two lateral sections (12 distinct fractures) in less than 8 hours from first pumping to final displacement. The resulting production rates far exceeded the operator's expectations. This paper presents a brief review of the hydrajet-fracturing stimulation process and specific details related to its highly successful application in this Level 1 dual-lateral completion.

Background

In 1998, Key Production Co. acquired the production and drilling rights to several leases in Hardeman County, Texas (**Fig. 1**). Of specific interest is production from the Meramec and the Chappel formations. In this region, the Meramec is primarily a limestone formation, and the Chappel is a moderate- to low-permeability limestone/dolomite reservoir that produces oil from approximately 7,800 to 8,200 ft and overlies the Ellenberger Aquifer. Typically, where the Chappel has been more completely dolomitized, there is better permeability and porosity, yielding higher production rates.

Primarily, conventional vertical well completions have been employed throughout this field. Two of the more common completion methods used are represented in **Figs. 2** and **3**. Both of these completion plans drilled a 12 $^{1}/_{4}$-in. hole to approximately 500 ft and cemented in 8 $^{5}/_{8}$-in. surface pipe. As shown in Fig. 2, some wells were then drilled into the Chappel formation until porosity was found. If a drill stem test (DST) indicated oil was present, the 5 ½-in. casing was run with a formation packer shoe on bottom. The packer shoe was set in the tight lime above the porosity and the casing was cemented. The shoe was drilled out and the well completed opehnole, typically without any type of stimulation treatment. Another common completion method used (**Fig. 3**) continued drilling into the primary-hole well into the Chappel lime 100 to 400 ft, depending on the local geology of the reservoir. The 5.5-in. casing was run to total depth (TD) and cemented back to 500 feet above the Meramec. These wells were completed by perforating and, if required, acid stimulated.

From the early to mid-1980s, some wellbores were plugged and abandoned as dry holes with no casing being set. After studying the geology of the reservoir, Key Production Co. believed that some of these locations could be re-entered and economic production rates achieved using short-radius, moderate-length, openhole horizontal laterals. **Fig. 4** is a schematic representing one of the abandoned wellbores recompleted as a horizontal well. In a part of the field considered low-quality, the operator decided to recomplete one of the abandoned wellbores in the Chappel lime as a Level 1 dual-lateral completion, with the laterals at similar depths and opposed by 90° (**Fig. 5**). The laterals were approximately 780 and 800 ft in length. After completing the second lateral and swabbing/flow-testing the well for two weeks, the team decided that some form of production enhancement treatment was needed to achieve optimum production rates.

Because formation permeability was low, the benefits of a simple acid wash to remove possible drilling damage did not seem cost-efficient. Fracture acidizing offered the degree of stimulation needed; however, there was concern that it might

lead to undesired communication with the aquifer zone below the oil column if fracture growth was excessive. After considering conventional methods[1-4] for "damage removal" or "stimulation," a low-risk, cost-effective alternative did not seem to be available. Conventional stimulation methods could not achieve multiple, well-spaced, limited size fractures in openhole laterals without high-cost/high-risk mechanical isolation methods.

This well was a good candidate for a newly evolving stimulation process that combines hydrajetting and hydraulic fracturing using a bottomhole assembly (BHA). In other areas, the process was showing a high success rate in single-lateral openhole completions. This new method first hydrajets tunnels into the walls of the wellbore, and then utilizing separate injections down the treating string (through the BHA) and the annulus, initiates and extends a fracture only at that location and at that time. Each stage used gelled 28% HCl acid to create an etched fracture face to achieve high fracture conductivity for an extended distance, but each fracture stage was kept relatively small in an effort to not communicate with the water zone below. This process seemed capable of achieving the exact type of stimulation needed for this well at an acceptable cost and at a low risk.

Hydrajet-fracturing was applied. The outcome was six separate fractures placed at selected locations along each of the two lateral sections (12 distinct fractures). This application was the first multilateral treatment and resulting production response proved its value for application in multilateral openhole completions.

Hydrajet-Fracturing Technique

This newly emerging fracture-acidizing or proppant-fracturing stimulation process is especially suited for horizontal wells. Earlier papers[5-10] introduced the basics of this concept and discussed some of the original field trials. Since that time, the tools and the methods for applying the process have been improved and several more recent field applications have been published.[11-13] The hydrajet-fracturing method uses dynamic fluid energy to jet a tunnel into the reservoir rock, initiate a hydraulic fracture from the tunnels, and isolate the fluid flow into the fracture at a specific point along the wellbore. When the desired stimulation treatment for that wellbore location is completed, the jetting/fracture-placement tool is quickly moved to a new position closer to the heel, and the next hydrajet-fracturing stage is executed (**Fig. 6**). With this new process, the fracturing operation is repeated without mechanical or chemical plug isolation from fractures just created.

This process is repeated as many times as desired, and job size at any specific location can be varied as needed. The ability to place multiple fractures at precise locations during one continuous well intervention, usually during one day, is extremely cost-efficient and offers significant risk reduction. Several previous papers have reported this new stimulation process, but this well was its first application in a multilateral completion.

Implementation on a Multilateral Well

During January of 2002, a multifracture acid stimulation treatment in a dual-lateral well was performed by Key Production Co. on the Hurst 2H well in Hardeman County, Texas. This well was a recompletion of a dry hole drilled in the mid-1980s that was plugged and abandoned without setting pipe, similar to Fig. 4. After drilling out the containment plugs, the hole was conditioned and a fracture identification log was run. Analysis of the log helped identify fracture orientation and the target zone for each lateral. The hole was plugged back with cement and 5 ½-in. casing was run to 8,016 ft and cemented. The original hole was sidetracked at 8,036 ft and a horizontal lateral was drilled at 300° azimuth orientation, to a target at 8,160 TVD, and horizontal section of 735 ft. A second horizontal lateral was drilled with a kickoff point at 8,042 ft and azimuth orientation of 45° (**Fig. 7**). The target TVD was 8,220 ft with a horizontal section of 795 ft. Both laterals were drilled with 4 ¾-in. OD bits.

From the known geology of the area of this well location, there was concern that nearby bottomwater might be within 100 ft below the laterals; therefore, a treatment design was selected that would place six small- to moderate-sized fractures in each lateral. Each stimulation point was selected based on drilling breaks, oil shows, and slight changes in lithology seen while drilling. Because the formation was a highly acid-soluble limestone, 28% HCl acid was selected as the stimulation fluid. Having considered the limitations of available conventional stimulation options, the operator decided to apply the hydrajet-fracturing technique. This technique seemed to be the best method capable of meeting the stimulation requirements for this well. It also offered low risk of communicating with the water zone below the laterals.

Considering the azimuth orientation of the laterals and the anticipated fracture plane, a tool designed to place fractures perpendicular to the wellbore was chosen (**Fig. 8**). The fractures were expected to initiate perpendicular to the wellbore (along the direction of the jetted cavities) and then realign slightly into the preferred fracture plane (PFP), probably within 5 to 15 ft. An overhead view of this anticipated result is shown schematically in **Fig. 9**, assuming a probable fracture direction as shown. For simplification, only half of the actual (twelve) fractures are shown in this sketch for simplification.

Through earlier experiences with tripping pipe in this well, the operator found that a wellsite-fashioned bent sub (**Fig. 10**) provided a good method to allow entry into either of the two laterals. Essentially, the sub is a joint of tubing with a mule shoe cut on bottom and a slight bend approximately 2 ft from the cut end. For the hydrajet-fracturing treatment, this bent sub was attached to the bottom of the hydrajet-fracturing BHA. The only way of identifying the lateral that was entered was to tag the toe because one had a MD of 113 ft more than the other had. After ascertaining which lateral was entered, the operators knew the pipe manipulation needed to pull out and then enter the other lateral.

A workover rig was used to place the treating string and tool assembly in the hole and to "wet strip" pipe joints under

pressure between fracturing stages to place the BHA at the proper wellbore location for the subsequent stage with only reservoir bleed-off of wellbore pressure. In **Fig. 11**, the bent sub joint has been inserted and screwed onto the bottom of the hydrajet-fracturing BHA.

The hydrajet-fracture acidizing job was completed without significant problems. With the bent joint, each lateral was entered on the first attempt (no concern existed regarding which would be treated first). The complete job of placing six fractures in each lateral (twelve total) was completed in one day, in approximately 7.5 hours from first pumping downhole to the final flush of Stage 12. When the treating string was withdrawn from the first lateral and inserted into the second lateral, only about 30 to 40 minutes extra time was required as compared to simply pulling joints between fracturing stages. Acid was pumped down a 2 $^{7}/_{8}$-in. tubing string and through the hydrajet-fracturing BHA at 16 to 20 bbl/min with wellhead pressures of 6,000 to 9,200 psi, but more typically 7,500 to 8,500 psi, for most of the 12 stages. Gelled water was pumped down the annulus at 11.5 to 15.6 bbl/min at pressures of 1,900 to 2,200 psi. Average size for each stage was 4,000 gal of acid and 150 bbl of gelled water. Pressure falloff was recorded for 10 minutes after each stage before the tool repositioning operation was started.

Production Response

Both pre- and post-fracture production data are shown in **Fig. 12**. Because this well was considered to be in an area of the field with below average porosity development, the operator was extremely pleased with the production response.

After about three months of producing, production seemed to be limited by pumping capacity; annulus fluid levels were typically within 200 to 500 ft of the surface. The operators decided to install a larger pump unit on the well to more effectively determine the productive capacity of the well, as this could affect the completion methods chosen for future wells in this field. The rod-pump was removed and the tubing string pulled. An electric submersible pump was then installed. Because the operator had not used this type pump in any wells in this reservoir, there was a significant learning curve to optimize fluid delivery from this well. Variables such as pump depth, horsepower of the electric motor, the surface choke size to pump against, and the frequency of the electric power to the motor were some of the interrelated variables involved. Production varied during the timeframe of pump optimization, and only a short period of stabilized production data was available for inclusion here. These data (**Fig. 13**) suggest that a 30% or more improvement in production capacity may be realized with the new pump, but more producing time is needed to fully determine the result.

Summary

This application was the first attempt to implement the hydrajet-fracturing process in a dual-lateral completion, and production results prove its stimulation effectiveness. This precedent established that this evolving new process is not limited to stimulation of single-wellbore openhole completions, although some wells could present more difficult or complicated re-entry conditions. By the end of July 2002, more than 60 wells were stimulated with either hydrajet-fracturing or the hydrajet-squeeze process (**Table 1**). Included in this number are three other multilateral completions that have been fracture stimulated using this process subsequent to the well discussed in this paper. These other three multilateral wells included both proppant fracturing and acid fracturing and all achieved excellent production response.

With the ability to effectively control placement of separate fractures at multiple locations along the wellbore, while also choosing the size of each fracture stage independently, an untold number of wells now could be stimulated with this low-risk and cost-effective stimulation process.

Conclusions

- The hydrajet-fracturing process was effective in stimulation of this dual-lateral openhole completion without increasing the relative water cut.
- Without any problems in moving from one lateral to another, the hydrajet-fracturing process is very suitable for use in stimulation of multilateral openhole wells.
- Maximized benefits from stimulation with this method will be realized when the completion allows for adequate pressures and injection rates to achieve fracture sizes that can optimize production response.
- The hydrajet-fracturing process offers fracture-stimulation possibilities for openhole horizontal wells that previously available technology could seldom achieve with either fracture acidizing or proppant slurry placements.
- The hydrajet-fracturing process has proven very successful in several multilateral well stimulations.

Acknowledgements

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Table 1—Summary of Applications of the Hydrajet-Fracturing and Hydrajet-Squeeze Stimulation Techniques as of July 2002

	Number of Wells	Cased	Liner	Openhole	Vertical	Horizontal	Deviated	MultiLateral	Frac	Squeeze	Acid	Sand as Proppant	Other Proppants	Gas in Annulus	Tubing	Coil	Success?
	1			✓		✓			✓				✓		✓		T, 1
	8			✓		✓			✓			✓			✓		E, 3; T, 4; F,1
	8			✓		✓			✓		✓				✓		E, 6; T, 1; F, 1
	2			✓		✓			✓		✓					✓	E, 1; T, 1
	3			✓		✓			✓		✓			✓		✓	E, 1; T, 1; F, 1
	2			✓		✓			✓		✓			✓	✓		E, 2
	10			✓		✓				✓	✓			✓		✓	E, 10
	5	✓			✓				✓			✓			✓		T, 4; F, 1
	2	✓			✓				✓		✓			✓	✓		E, 2
	2	✓					✓		✓			✓			✓		E, 1; T, 1
	6	✓				✓			✓			✓			✓		E, 1; T, 2; F, 3
	3		✓			✓			✓			✓			✓		T, 3
	3		✓		✓				✓			✓			✓		T, 3
	1	✓				✓			✓			✓				✓	E, 1
	1	✓		✓		✓			✓				✓			✓	E, 1
	1			✓	✓				✓		✓					✓	E, 1
	2			✓		✓		✓	✓		✓				✓		E, 2
	1			✓		✓		✓	✓		✓	✓			✓		E, 1
	1			✓		✓		✓	✓			✓			✓		E, 1
Summarized Totals	62	17	6	40	11	48	2	4	52	10	31	30	2	17	44	18	E, 34; T, 21; F, 7

Number of Wells Cased Liner Openhole Vertical Horizontal Deviated MultiLateral Frac Squeeze Acid Sand as Proppant Other Proppants Gas in Annulus Tubing Coil Success

Note: E - Economical & Technical Success
T - Technical Success
F - Fail

Note #2: Technical Success means that the process produces fractures as planned; but the well does not produce at economical levels.

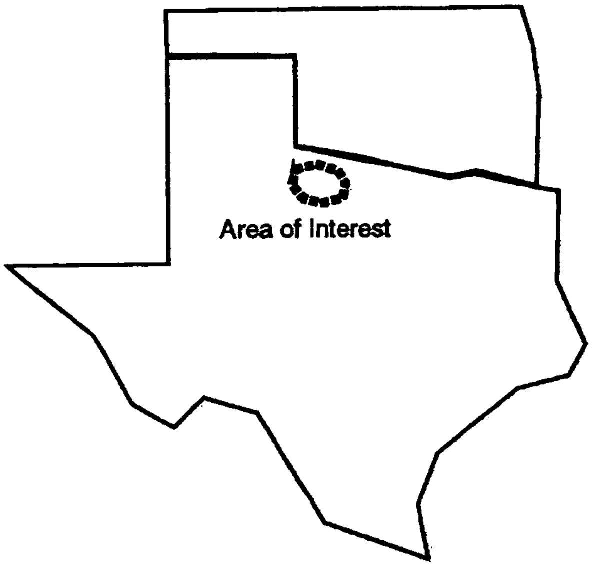

Fig. 1—Approximate field location of dual-lateral well.

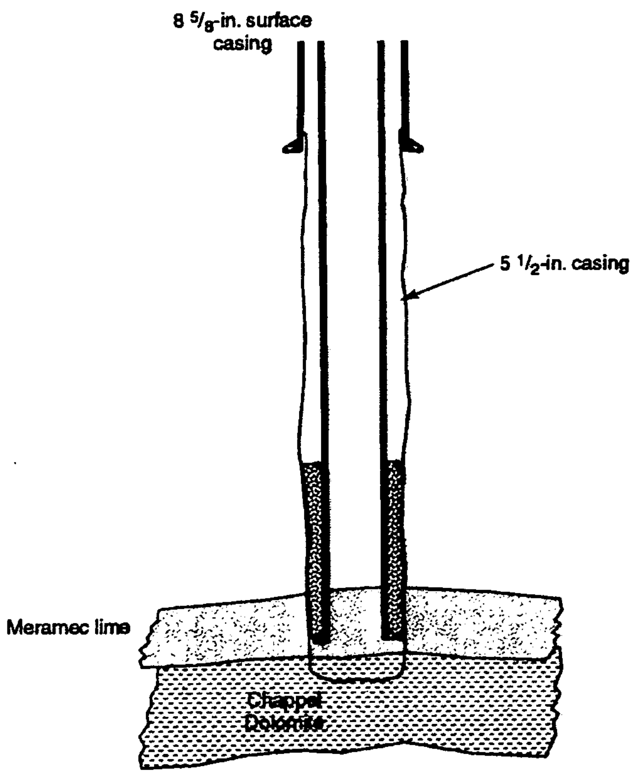

Fig. 2—Typical vertical completion in the field utilizing openhole method.

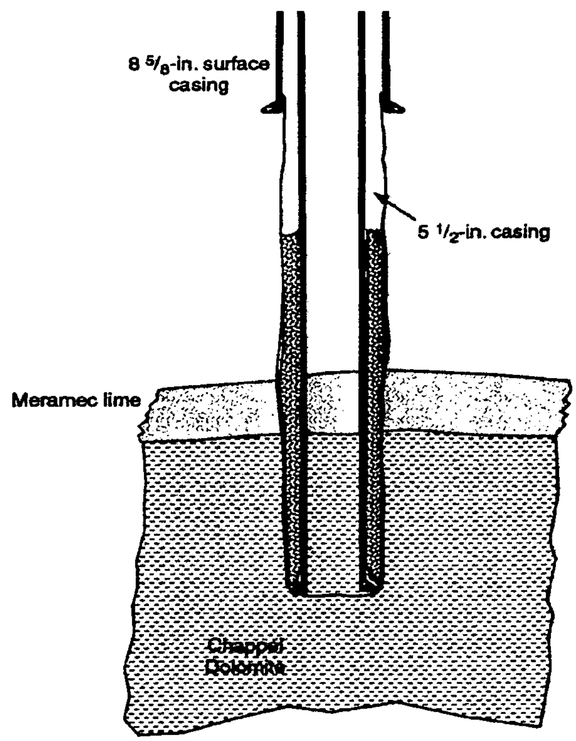

Fig. 3—Some vertical completions were cased/cemented/perforated.

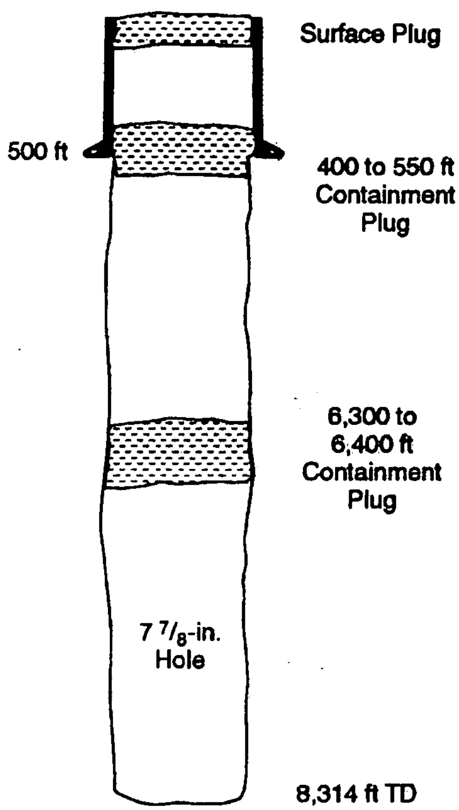

Fig. 4—Schematic representation of abandoned wellbores.

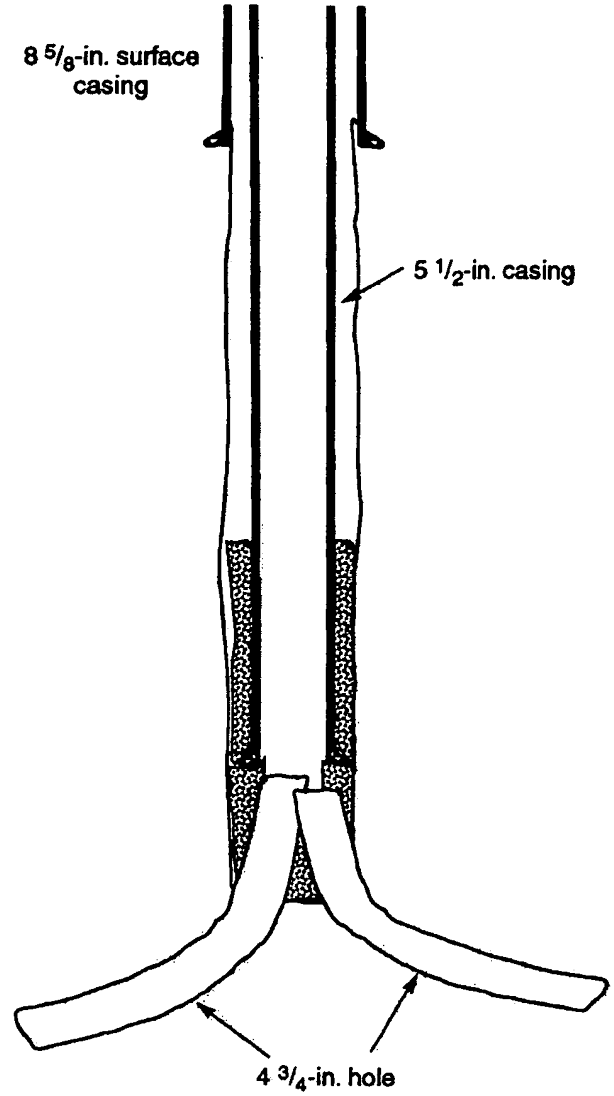

Fig. 5—Recompletion of an abandoned wellbore in the Chappel lime as a dual-lateral well.

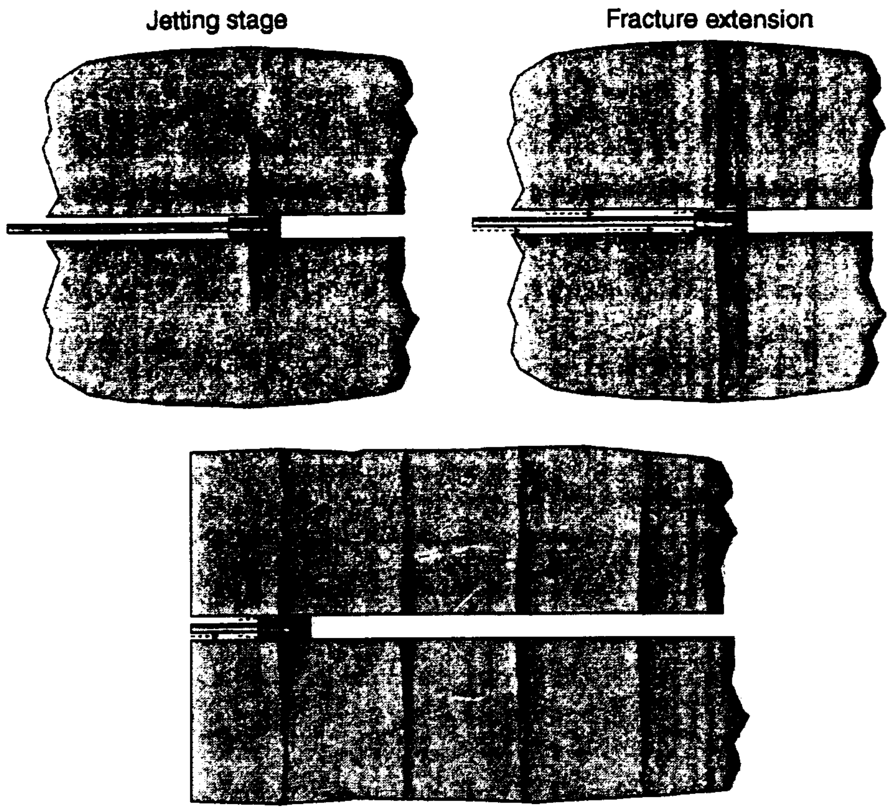

Fig. 6—Hydrajet-fracturing technique.

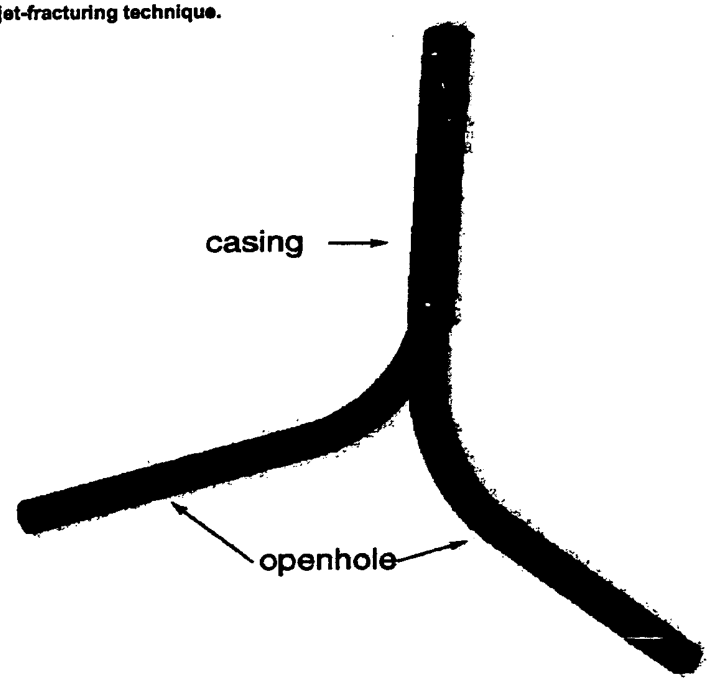

Fig. 7—Subject well was a recompletion of an abandoned wellbore as a Level 1 dual-lateral well with the laterals at similar depths and opposed by 90°.

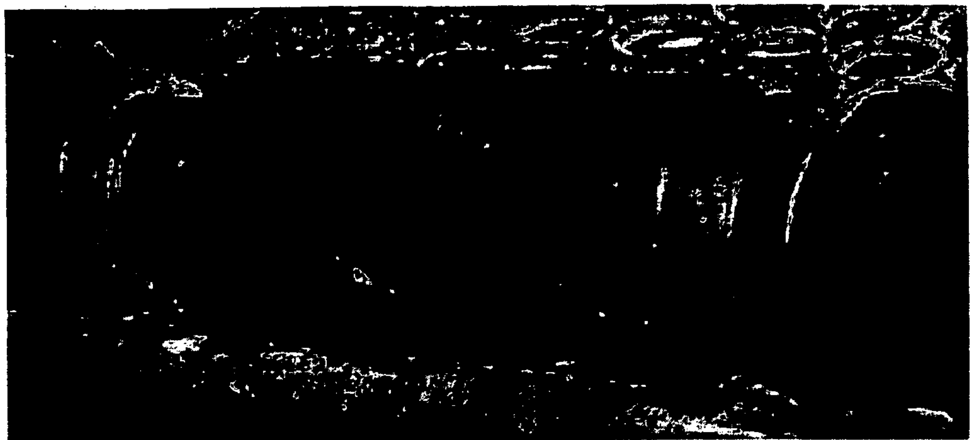

Fig. 8—Jet section of the BHA lying on the rig floor before being run in the hole.

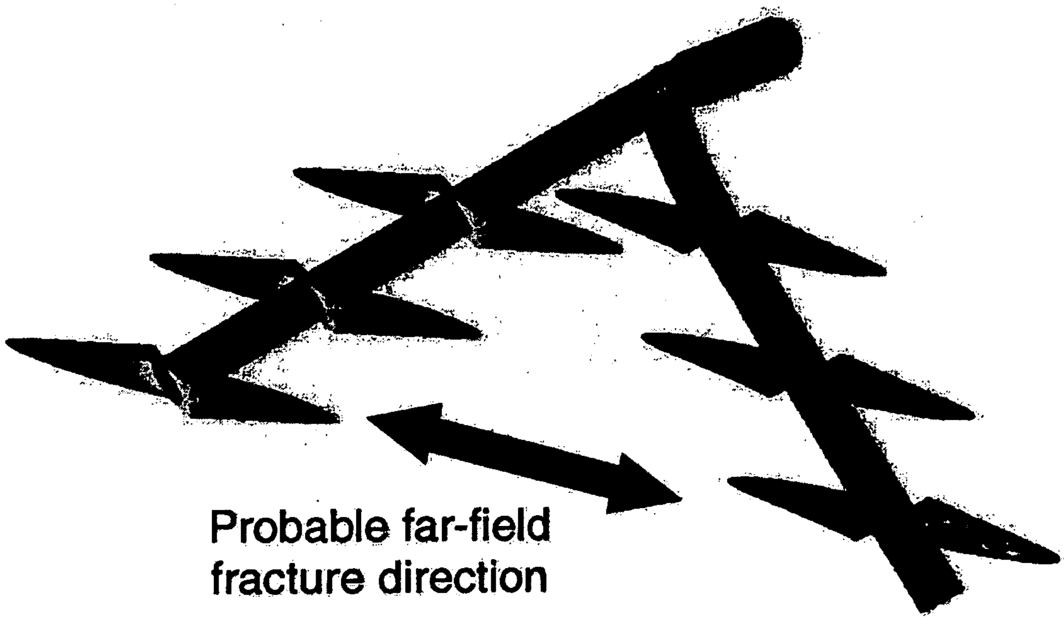

Fig. 9—Overhead view of the anticipated results.

Fig. 10—Wellsite-fashioned bent sub that enabled entry into either lateral.

Fig. 11—Bent sub joint inserted and screwed onto the bottom of the hydrajet-fracturing BHA.

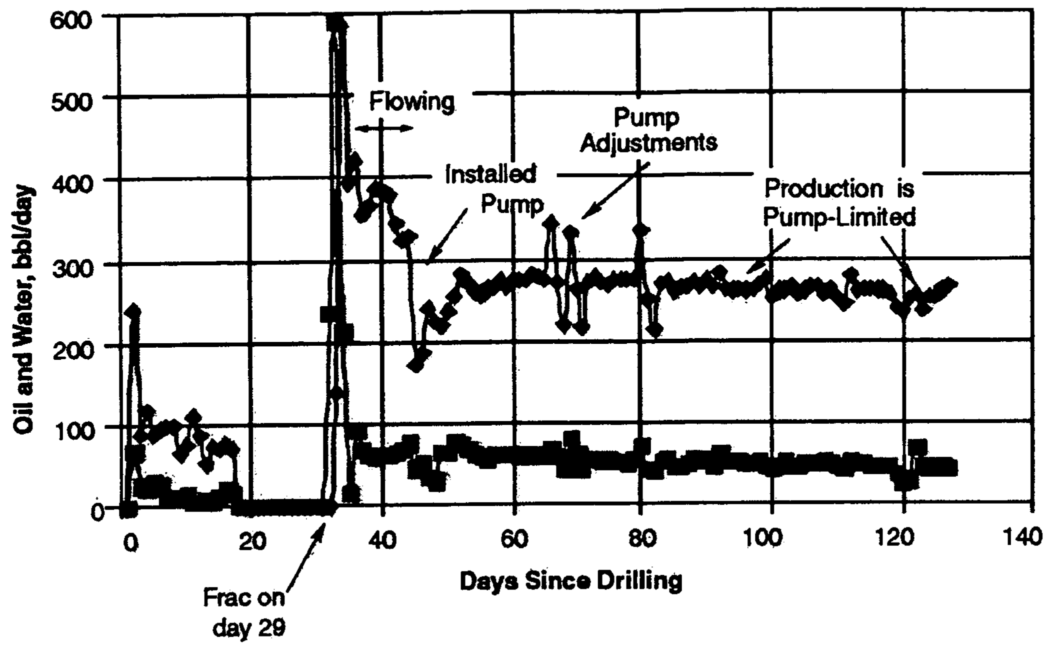

Fig. 12—Pre- and post-fracture production data.

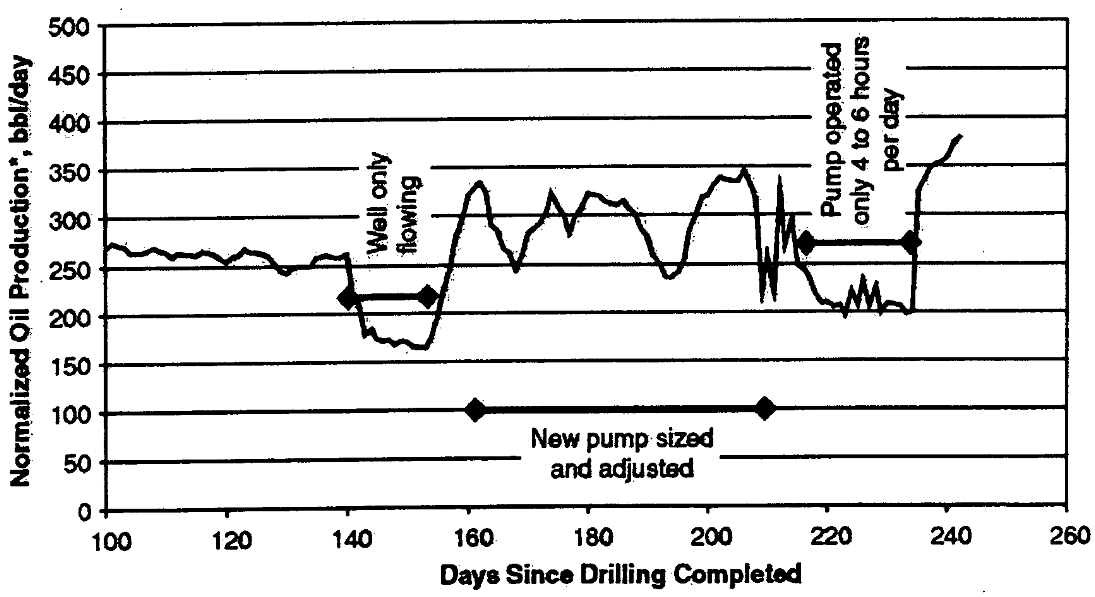

Fig. 13—Production only 100 days after drilling illustrates the effect of the new pump. Final few data points (daily rates) are believed to be representative of the net benefit.